SPECIFICATION

To All Whom It May Concern:

Be It Known That I, Joseph E. Schroeder, a citizen of the United States and a resident of the County of Franklin, State of Missouri, whose full post office address is 46 Fernwood Drive, Union, Missouri 63084, have invented certain new and useful improvements in

ONCE-THROUGH EVAPORATOR FOR A STEAM GENERATOR

CROSS REFERENCE TO RELATED APPLICATIONS

This application derives and claims priority from U.S. Provisional Application Serial No. 60/416,083, filed October 4, 2002.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

Not Applicable

BACKGROUND OF THE INVENTION

This invention relates in general to steam generators and, more particularly, to an evaporator for a steam generator and tubing for such an evaporator.

Steam finds widespread use in industry, perhaps the most important of these uses being the generation of electrical power. Typically, hot gases, in many instances generated by combustion, pass through a steam generator which converts water into superheated steam. Representative of these installations are heat recovery steam generators (HRSGs) which are used to extract heat from the hot gases discharged by gas turbines that drive electrical generators. The heat extracted produces steam which passes on to a steam turbine that powers another electrical generator.

The typical steam generator, aside from a duct through which the hot gases pass, in its most basic form, includes three additional components – namely, a superheater, an evaporator, and an economizer or feedwater heater arranged in that order with respect to the flow of gases in the duct. The water flows in the opposite direction, that is through the economizer where it is heated, but remains a liquid, then through the evaporator where it is converted into mostly saturated steam, and then through the superheater where the saturated steam becomes superheated steam.

Evaporators come in two basic configurations – the circulation type and the once-through type – each with its own advantages and disadvantages. Both have an array of tubes in the duct through which the hot gases pass.

In the circulation type, the tubes reside in a circuit with a steam drum that is above the tubes. The drum contains water which flows from the drum, through a downcomer, and then into the tubes where some of it is converted into steam, but the steam exists as bubbles within the water, and is returned through a riser into the steam drum. Here the steam, which is saturated, separates from the liquid water and passes on to the superheater. It is replaced by feedwater which is supplied to the drum. The tubes of a circulation evaporator remain wet all the time – that is to say, liquid water exists against their interior surfaces throughout. This promotes good heat transfer. It also maintains the tubes at relatively moderate temperatures, thus eliminating the need for high temperatures alloys in the tubing.

But circulation evaporators have their detractions. Perhaps the greatest of these is the expense attributable to steam drums, large downcomers, and headers to supply water to their tubes. Moreover, the reservoirs of water contained in them require time to bring up the boiling temperature, so the start-up time for a circulation evaporator is extended.

Once-through evaporators do not require downcomers or drums and are less expensive to manufacture. Moreover, the only stored water in them resides in the tubes themselves and the supply header from which the tubes extend. This enables a once-through evaporator to be brought to operating conditions more rapidly than a natural circulation evaporator. However, a once-through evaporator must completely convert the water into steam, so that only steam escapes from its tubes and flows on to the superheater.

No liquid water should leave the evaporator. The evaporator relies on a feedwater pump located upstream in the water circuit to circulate water through it at a controlled rate – a rate that if correct allows the steam to leave in a saturated or a slightly superheated condition.

Thus, in a once-through evaporator the tube walls nearest to the water inlet run wet as in a circulation type evaporator, because these ends of the tube see only liquid water. But farther on in the tubes the water turns into a mist and then into saturated steam. In the mist flow regime, water is sheered from the interior surfaces of the tube walls, so the mist exists in cores which extend through the centers of the tubes. The walls around these cores run dry. This produces higher temperature in the tube walls and less efficient heat transfer. The higher temperatures may require metals that are better able to withstand these temperatures or, in other words, a resort to expensive high alloy steels.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

Figure 1 is a schematic sectional view of a steam generator equipped with a once-through evaporator constructed in accordance with and embodying the present invention;

Figure 2 is a perspective view of the evaporator;

Figure 3 is a sectional view taken along line 3-3 of Fig. 2;

Figure 4 is a fragmentary sectional view of the end of one of the evaporator tubes showing a twisted tape anchored in the tube;

Figure 5 is a fragmentary sectional view similar to Fig. 4, but rotated 90°; and

Figure 6 is a fragmentary view of one of the evaporator tubes, partially cut away and in section, showing the flow in the tube.

DETAILED DESCRIPTION OF INVENTION

Referring now to the drawings, a steam generator A (Fig. 1) basically includes a duct 2 having an inlet end 4 and a discharge end 6. The inlet end 4 is connected to a source of hot gases, such as a gas turbine or an incinerator, and those gases flow through the duct 12, leaving it at the discharged end 6. In addition, a steam generator A includes a superheater 12, an evaporator 14, and a feedwater heater or economizer 16 arranged in the duct 2 in that order from the inlet end 4 of the outlet end 6. Thus, the hot gases flow first through the superheater 12, then through the evaporator 14, and finally through the economizer 16. Water flows in the opposite direction. To this end, the economizer 16 is connected to a feedwater pump 18 which delivers feedwater to the economizer 16. It extracts heat from the hot gases and transfers that heat to the liquid water that flows through it, thereby elevating the temperature of the water, but the water remains a liquid. Leaving the economizer 16, the liquid water then flows to the evaporator 14 through which it passes. The evaporator 14 converts the water to steam, mostly saturated steam. The steam flows into the superheater 12 which raises its temperature, transforming it into superheated steam that may be used to power a turbine or in some industrial process or even to heat a building. The superheater 12, evaporator 14, and economizer 16 are basically tube banks. The evaporator 14 operates on the once-through principle. Actually, the steam generator A may have more than one evaporator 14.

The evaporator 14 includes (Fig. 2) a supply header 26, a discharge header 28 and tubes 30 which extend between the two headers 26 and 28. The supply header 26 has an inlet port 32 that is connected to the economizer 16 and receives heated water from the economizer 16 - indeed, water which is delivered to it under the head produced by the pump

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Within the tubes 30 the heated water from supply header 26 is converted into the steam which collects within the discharge header 28 and then passes on to the superheater 12. Thus, the portion of each tube 30 that is closest to the supply header 20 contains liquid water, while the portion that is closest to the discharge header 28 contains steam that is saturated and perhaps even slightly superheated. In the intermediate portion of each tube 30 the liquid water undergoes the change of phase and becomes steam. Here the water boils, becoming a mist or a mixture of water and saturated steam. Further along the mist becomes saturated steam, and finally the saturated steam may become superheated steam, albeit only slightly superheated. The superheated region of the tube 30, if indeed there is superheated steam, is quite short. The tubes 30 are formed from carbon steel or chrome-moly steel.

Each tube 30 contains a helical tape 40 (Figs. 3-5) which extends from its inlet and, that is its end which is connected to the supply header 26, through the regions in which the mist exists. The width of each tape 30 is slightly less than the inside diameter of the tube 30 through which it extends, so that the tape 40 can be inserted into or withdrawn from the tube 30 without interference from the tube 30 itself. Preferably, the width of each tape 40 should be about 1/16 inches smaller than the inside diameter of its tube 30, at least for a tube having a 2 inch inside diameter. The tape 40 is twisted multiple times between its ends, so that its edges form helices that lie along the inside surface of the tube 30. Indeed, a full 360°

twist of the tape 40 should occur within a distance amounting to a length to diameter of 5 to 25. For example, for a tube 30 having a 2 inch inside diameter and a length to diameter ratio of 5 for the twist in its tape 40, a full 360° twist of the tape 40 will occur in 10 inches of the tube 40. That end of the tape 40 that resides at the inlet of the tube 30 is fitted with an anchor bar 42 that extends transversely across like inlet end of the tube 32. The bar 42 is welded to the end of the tube 30 and to the tape 40, thus anchoring the tape 40 with its tube 30. The tapes 40 are formed from a metal that can withstand the temperatures associated with slightly superheated steam and are further compatible with the metal of the tube 30 in the sense electrolytic reactions are minimized. Stainless steel is suitable when the tubes 30 are carbon steel.

In the operation of the steam generator A, hot gases flowing through the duct 2 pass over the tubes of the superheater 12, the evaporator 14 and the economizer 16 in that order and at each undergo a reduction in temperature. The feedwater pump 18 forces water into and through the economizer 16 where the water extracts heat from the gases that flow over the tubes of the economizer 16. The temperature of the water rises, but the water remains in the liquid phase. Under the head produced by the pump 18, the water flows from the economizer 16 into the supply header 26 of the evaporator 14 and then into the tubes 30 of the evaporator 14. Within the tubes 30, the water encounters even higher temperatures derived from the gases passing through the duct 2. Indeed, the gases passing through the evaporator 14 elevate the temperature of the tubes 30 high enough to convert the water in the tubes 30 to steam. The water, initially upon entering the tubes 30, remains in the liquid phase, but as it flows through the tubes 30 it begins to boil, producing a mist. The tapes 40 extend through the region of mist flow and produce a good measure of turbulence in the

mist as it flows on toward the discharge header 28. The turbulence brings the mist, that is to say the water particles, against the inside surfaces of the tubes 30 (Fig. 6), thereby effecting better and more efficient transfer of heat between the gases flowing over the tubes 30 and the mist in the tubes 30. This further protects the tubes 30 from overheating. Were it not for the tapes 40, the mist would tend to remain in the center of the tubes 30 and would be surrounded by saturated or superheated steam along the interior surfaces of the tubes 30, thus causing the tubes 30 in the regions of the mist to operate at higher temperatures. As the mist in the tubes 30 flows on and approaches the discharge header 28 it transforms into saturated steam and may even change to superheated steam, albeit only slightly superheated. But the regions of the tubes 30 that see only superheated steam are short and are maintained at relatively moderate temperatures by reason of heat conducted from them to the regions occupied by the mist and the liquid water.

In lieu of anchoring the tapes 40 to the tubes 30 at the supply header 26, they may be anchored at the discharge header 28, in which event they will extend toward the supply header 26. The tapes 40 may extend the full lengths of the tubes 30 through which they pass or only through the regions of mist flow. The evaporator 14 in lieu of having its tubes 30 arranged in a single bank, may have them organized in multiple banks.